Evolution of Home Automation Technology

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Abstract - In modern society home and office automation has become increasingly important, providing ways to interconnect various home appliances. This interconnection results in faster transfer of information within home/offices leading to better home management and improved user experience. Home Automation, in essence, is a technology that integrates various electrical systems of a home to provide enhanced comfort and security. Users are granted convenient and complete control over all the electrical home appliances and they are relieved from the tasks that previously required manual control. This paper tracks the development of home automation technology over the last two decades. Various home automation technologies have been explained briefly, giving a chronological account of the evolution of one of the most talked about technologies of recent times.

Index Terms - Home Automation Network, Wireless Control, Internet based Control

1. INTRODUCTION

At the advent of 1990s the average house started to have interaction with many electronic devices. There were regular electric appliances such as refrigerator, electronic appliances such as television, communication appliances such as telephone, and information appliances, such as computer. The functioning of all these appliances required dedicated wiring system so a normal residential environment had various wiring systems including power wiring, telephone wiring, and cable TV wiring. Some homes also had additional wiring for home security and PC local area network etc. All these systems used different types of communication media and carried different types of signals completely independent of each other. At the same time due to great advancements in IC technology the computing costs experienced a sharp decline and miniaturization process gained momentum making dedicated microprocessor a common part of home appliances which resulted in enhanced intelligence level of home appliances.

But this intelligence had not been utilized to its true potential as these appliances operated in complete isolation from each other. Under this scenario the need of a unified "home network" was felt keeping in mind various advantages it will offer such as (i) ease of use convenience, as an appliance can be controlled from different locations (ii) sharing of information, and (iii) minimum wiring confusion and low cost [1].

The working principle of an automated home is explained in section 2 of the paper. Some of the early developments in the field of home automation technology are detailed in section 3.

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Section 4 is focused on the recent developments in home automation. As the home automation technology is growing there are serious concerns arising about it's security. Section 5 of the paper is dedicated to the work done for enhancing security of the automated home.

2. WORKING OF AN AUTOMATED HOME

The key to control of appliances, in an automated home lies, in the ability of the products to communicate. The nature of these devices in a home network is very similar to that of other networks such as a computer network. Each switch or module has a unique "address". When a control signal is broadcast through the network, all of the modules in the network can hear the commands, but only those to which the signal is addressed will respond to it.

The majority of commands in conventional homes are passed on to the device in question through the use of a physically operated switch. Generally pressing a switch or turning a dial directly alters the supply of electricity to a device. The switch or knob opens or closes an electrical connection or varies the resistance of that connection. Fig.1 illustrates this using the example of a typical lighting circuit. The lamp in the circuit is linked to a separate switch that is able to interrupt the flow of electricity to the light fittings.

In an automated home the switch takes on a different function. Rather than regulating the flow of electricity, the switch merely sends a signal to a communication network, called a bus system, informing the network of the new position of the switch as shown in Fig. 2. A controller fitted to a single light fitting, or a number of light fittings, receives this signal, recognizes that the message is intended for it and responds, in this example by turning on the light. Therefore the regulation of electrical flow takes place at the controller rather than at the switch. If the bus system connects more than just lights, it is possible to radically change the way the home is controlled. The switch is no longer directly related to any particular device so it can operate any device on the network that has been told to respond to the signal from the switch [3]. So multiple lights, possibly in different rooms, could be controlled and even dimmed to different levels as illustrated in Fig. 3. In addition, it can also be seen from fig.3 that a single switch may be used to control various home appliances.

3. EARLY DEVELOPMENTS

Sensing the advantages associated with home automation network research and development projects started on a large scale around the world but the absence of a standard for the networking of home appliances appeared as the major roadblock which was removed in 1992 with the development of Consumer Electronic Bus or CEBus by the Electronic Industries Association of America [2].

The CEBus standard includes specifications for a layered network architecture based on the Open Systems Interconnection model, with network layer protocols for the Physical, Data link, Network, and Application layers. The main advantage of this standard is that the Physical Layer supports six different transmission media, namely twisted pair, coaxial cable, power line, infrared, radio frequency, and fiber optics. Thus the best physical medium for a given application can be selected. Cross & Douligeris [4, 5] proposed that fiber optics may be the best medium for home automation network because with fiber, the capabilities of the home automation system can be expanded to include many more functions, leading to complete home integration. They observed that although CEBus includes fiber optics as one of the physical media but it does not specify the configuration of the fiber optic network. Therefore they designed a fiber optics based home automation which offered various advantages such as (i) increased bandwidth, (ii) immunity to electromagnetic noise, (iii) ease of installation, and (iv) safety from electric shock hazards. As the designed network also had some drawbacks such as its higher cost and that optical fiber cannot carry direct current, so an alternate source of energy was required.

During early part of 1990s, the consumer electronics devices evolved into digital format, therefore the need was felt to interconnect these home appliances through digital links to preserve the fidelity of information transmitted. Chen [6] proposed a home automation network with the above stated purpose. Apart from digital link the main feature of the proposed home automation network was the Digital Aceess system which allowed the home network to communicate with the outside world also. Chen advocated the use of IEEE 1394 for the proposed network as it can handle both data and isochronous traffic well at a data rate above 100 Mbps.

Untill 1993, the home automation networks developed employed guided or wired media for interconnection of appliances. However Fujieda [7] felt that for achieving complete marketability, home networks should be easily installed not only to newly built houses but also to existing houses. So it would be desirable to build up networks without any extra wiring. Therefore he advocated the use of wireless media for home networking and called the network as wireless home networks. For the wireless home network he proposed the use of 400 MHz specified low power (SLP) band. Fujieda developed a low power and small size RF section of SLP band and communication protocol and demonstrated the proposed wireless network to be viable. Using the prototype he also implemented a couple of application systems, a maintenance system for instantaneous gas water heaters and a health promotion system with chronic disease prevention.

4. RECENT DEVELOPMENTS

Early generation appliances typically relied on a hard wired connection to a desktop computer in order to communicate with the outside world but during the past decade great advancements in Internet, Mobile telephony and TCP/IP technologies have resulted into many appliances having their own inbuilt communication transceivers; Infra Red, 802.11b, Bluetooth and GSM/GPRAS. Also development of new physical layer technologies has resulted into reliable transfer of data at a much faster rate. All these developments have changed the face of home automation technology also.

A critical analysis of some of the recent research and development efforts in the field of home automation is presented in this section.

In 2003 Hiroshi Kanma and others [8] observed that although the rapid spread of Internet at home may provide a convenient way of implementing a home network and its control, however there were certain hindrances to be removed to make home automation common such as (i) initial cost of introducing the home network system and the control terminal equipment, (ii) difficulty in simultaneously replacing all home appliances for networking , and (iii) the lack of mobility in the control terminal. To solve all these problems Kanma proposed the use of Bluetooth as communication medium and a cellular phone as the terminal equipment. A communication adapter was attached to the home appliances in order to provide a Bluetooth communication functionality which eliminated the need of purchasing new appliances for the home network. A simplified overview of the proposed network is shown in fig.4. In addition they postulated that the cellular phone will provide short start up time and its ability to access internet can provide certain other useful functionalities and services. Hardware and software for these adapters, Java applications running on the cellular phone and the interface software between the Java applications and the adapter were made for the prototype. Further developments in this direction have been done on various Bluetooth kits/boards produced by Man n Tel, Korea [9,10].

At the same time Tajika and others [11] articulated that the home network technology was focused primarily on how data and access protocols on the Internet can be utilized in the home network by converting them into in-house protocols through a home gateway. However they felt that apart from control only, other novel services can be provided to home through the Internet resulting in better user experience with out any enhanced complexity and without any loss of flexibility and portability. The system proposed by them composed of networked home appliances such as refrigerators, microwave ovens, air conditioners, and washing machines, Bluetooth access point and home terminal in a home. Bluetooth units were embedded within all the appliances and these wee connected to the Internet. Home terminal was connected to the home network and the Internet and it provided a well designed GUI to the user through touch panel and voice recognition and it also worked as a gateway between the home network and the Internet service provider. The overview of the proposed network is shown in fig.5. The authors developed some actual functions for each home appliance, such as cooking mode/timer settings for a microwave oven or monitoring stocks through a sensor in the refrigerator. ECHONET ver3, a specification for control/monitoring a function in home appliances was included in the system. It defines control/monitoring interface of

functions for white appliances, sensors and healthcare appliances.

In 2005 Hayong Oh and others [13], highlighted the importance of energy efficient routing scheme for the sensors placed in the home. According to the authors, in the emerging automated home, sensors are required to be placed everywhere in the house to collect various physical data such as temperature, humidity, and light to provide information to various appliances. For example, the heating system senses the temperature of the home and controls it according to the weather. The authors argued that in the conventional sensor routing scheme each sensor node detects an event and broadcasts the event to all sensor nodes within one hop range from where all the nodes broadcast the message to the next nodes. This process is recursively performed until the event reaches the base station. This scheme leads to excessive drain of battery power and as these sensor nodes have limited battery power, an energy efficient sensor routing scheme is critical for the successful implementation of home network. Therefore they proposed a new sensor routing scheme for home automation networks and called it as RDSR (Relative Direction based Sensor Routing). The proposed scheme divides the home area into sectors and locates a manager node to each sector. The manager node receives collected data from sensor devices in its sector and then transfers the data to the base station through the shortest path of the 2-dimensional (x, y) coordinates. The proposed scheme was shown to be energy efficient.

In 2006 Mario Kolberg and Evan H. Magill [14] addressed the control of complex networked appliances. Currently a standard computer interface is most often used to configure and remotely control these appliances. However the authors argued that this is unsuitable for the target audience which is often inexperienced with the use of computers. Therefore they proposed Anoto-enabled pen and paper as a suitable alternative as users are highly familiar with pen and paper and they will find it suitable for control. In the proposed system Bluetooth and mobile telecommunication network is used to transfer data to a service provider where it is processed and sent to the user's home. It was shown that the approach can be used to control a number of different appliances in the home and also outside the home.

5. SECURITY ISSUES

In 2003 H. Nakakita and others [12] addressed the problem of security of wireless home network. They observed that considering the advantages offered by Bluetooth as communication medium in wireless home networks, it is expected to be applied to all the home networks in near future. However they felt that its wide spread acceptance will result into multiple home networks placed close to one another and they will operate simultaneously in an overlapped area. In these circumstances, a wireless home network may encounter serious security problems like eavesdropping from outside the home or masquerading as a member of the network. The authors proposed several requirements for a secure home network such as (i) separation of communication between inside and outside of home network, (ii) prevention of eavesdropping from outside the network, (iii) an easy method of adding new wireless appliances to the network, (iv) a way of deregistering unused, stolen, or discarded appliances from the home network.

The authors proposed a system fulfilling the above security requirements. The proposed network was a server based system to manage the wireless home appliances through the use of existing frameworks with encryption function in the data link layer. The system assigned a unique master key to each appliance and some shared network keys. The shared network key was periodically updated in order to ensure the security of the home network.
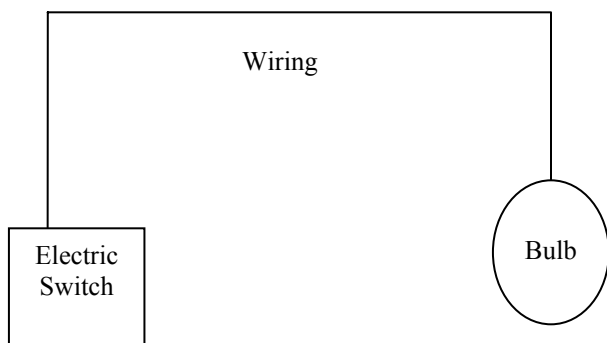
6. CONCLUSIONS AND SCOPE FOR FURTHER WORK

The journey of home automation technology has been critically investigated in this paper. It is observed that from simple interconnection and combination of household appliances it has evolved into a powerful technology for the networking of home appliances for the purpose of not only remote control but also for adding intelligence to the home and providing novel services resulting in great improvement in user experience. Furthermore, the revolutionary developments in the fields of high speed computing devices along with TCP/IP based internet, wireless and mobile communication have really helped in the rapid growth of home automation. The use of these technologies in home automation and networking is definitely going to increase in the years to come. In Indian context, this field is still in an infancy stage and deserves to be pursued rigorously.
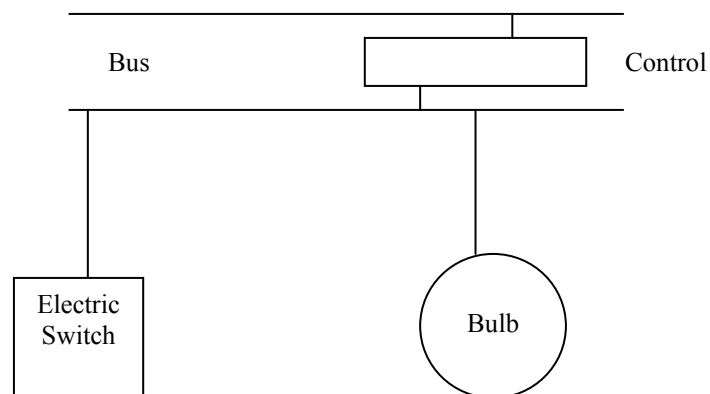
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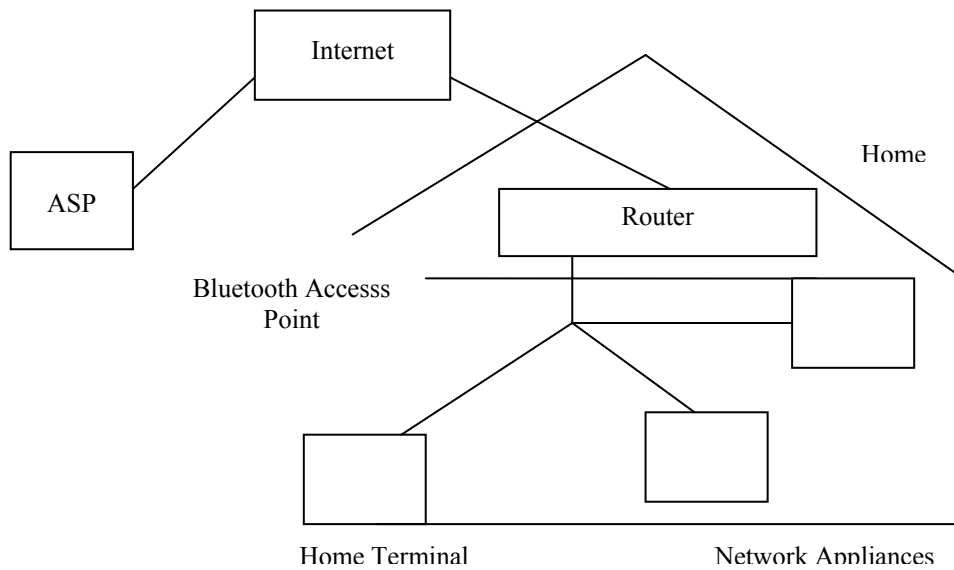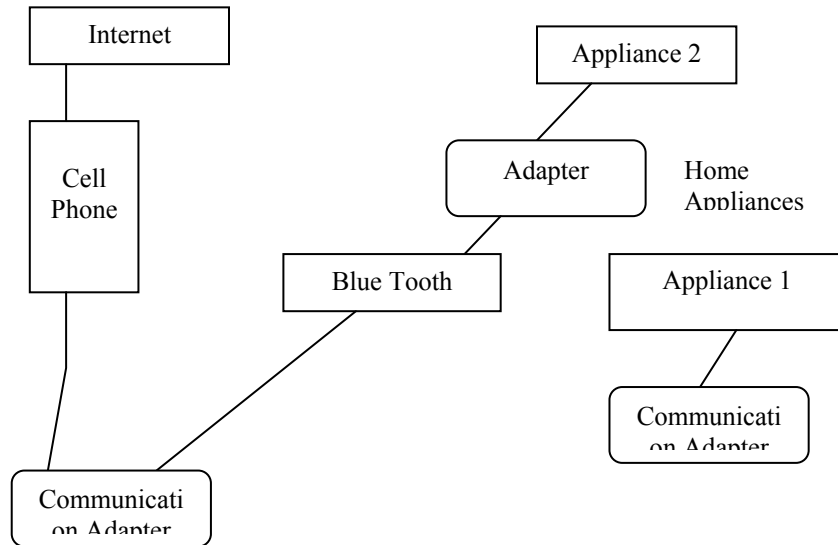
Figure 2: A Bus Controlled Lighting Circuit
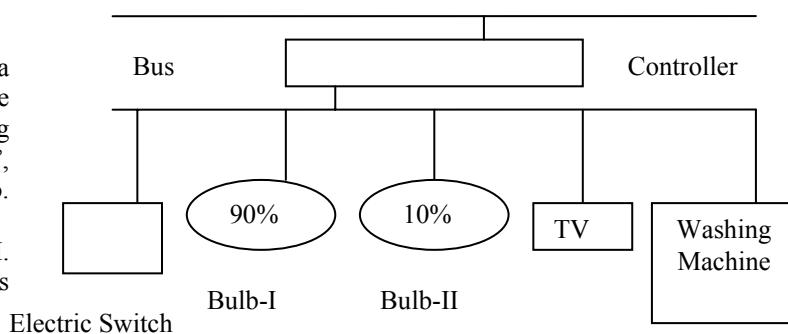
Figure 3: Bus System Controlling a Variety of Home Appliances

Figure 1: A Conventional Lighting Circuit

Figure 4: Overview of the Network

Figure 5: System Overview

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